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Future Consumption of Timber Growth in Northern Minnesota: 1980-2030

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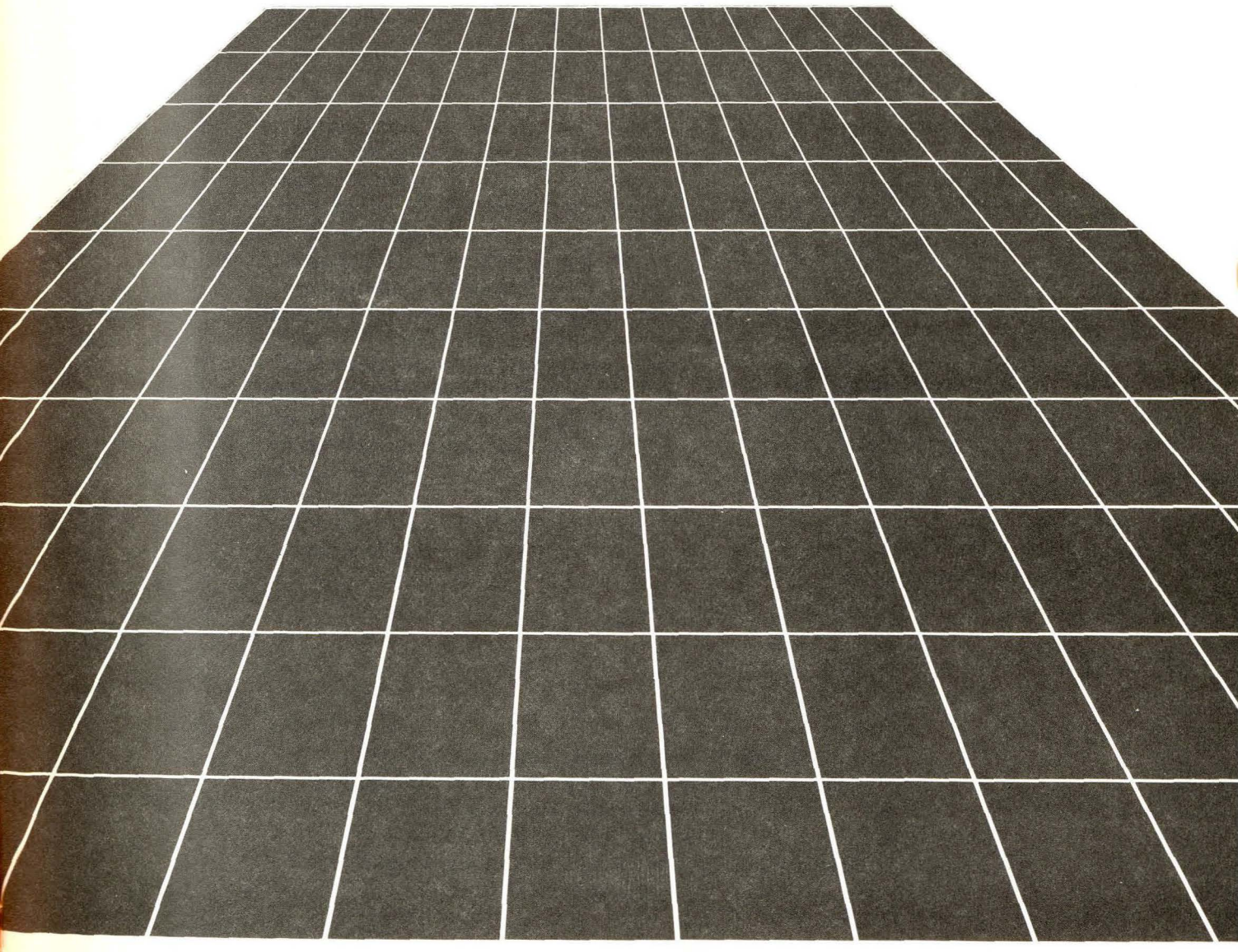

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FUTURE CONSUMPTION OF TIMBER GROWN IN NORTHERN MINNESOTA 1980-2030[1]

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The timber harvest of northern Minnesota[2] has always been a significant portion of the total State harvest. In 1975 the roundwood harvest in northern Minnesota was slightly more than 137 million cubic feet (1.73 million cords), which is nearly 87 percent of the total Minnesota roundwood harvest. Pulpwood is the largest component of the northern Minnesota harvest. Production has grown steadily, from 748 thousand cords in 1950 to 1.17 million cords in 1976.

Eight pulp mills in Minnesota and several mills in neighboring Wisconsin and Ontario presently consume wood harvested from this region. In addition, three flakeboard mills are currently purchasing pulpwood-size materials from this area. Another mill has been completed, but awaits start-up.

With the growth of wood using industries and fuelwood markets in Minnesota, both public agencies and private industries are concerned about the future demand for roundwood. The National Forest Management Act of 1976 (NFMA), the Rules for Carrying Out the Act in 1979, and the Boundary Waters Canoe Wilderness Act of 1979 (BWCWA) have specific provisions for determining future demand for harvested timber. The NFMA and the implementation rules require the individual national forests to estimate the present and future demands for timber from the forests so that they can plan their production activities. With the passage of the BWCWA, additional concern has risen regarding the future supply of commercially harvestable timber as more northern Minnesota forest land has been allocated for recreation.

The purpose of this paper is to present long-term projections of consumption for pulpwood, fuelwood, and saw logs grown in northern Minnesota. The latest Forest Service analysis of the timber situation in the United States (USDA Forest Service 1980) serves as the basis for the projections. We attempt to determine the implications of the Forest Service national and regional (North-Central) projections for northern Minnesota. For that reason, the basic projection interval (1980-2030) used in the national analysis is used here, as well as the same basic assumptions regarding demographic, economic, and construction growth. Additional assumptions are described throughout the remainder of this paper.

In this paper we present the following projections:

1. Northern Minnesota pulpwood consumed in pulp production.
2. Pulpwood used in construction board production (particleboard, flakeboard, and hardboard).
3. Fuelwood use.
4. Saw log consumption.

We also summarize projections of fuelwood, pulpwood, and saw log consumption in all uses for the northern Minnesota region, during the period 1980

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[1]*This study was conducted by the School of Natural Resources, University of Wisconsin, Madison, WI, in cooperation with the USDA Forest Service, North Central Forest Experiment Station, Duluth, MN.*

[2]*In this paper, northern Minnesota is defined by Forest Survey Units 1 and 2. These units are geographic areas used by the USDA Forest Service Resources Evaluation Project to report results of periodic inventories of the Nation's forest resources. Survey Unit 1 includes the counties of Cook, Lake, St. Louis, Carlton, and Koochiching. Survey Unit 2 includes Aitkin, Becker, Beltrami, Cass, Clearwater, Crow Wing, Hubbard, Itasca, Lake of the Woods, Mahnomen, Roseau, and Wadena counties.*

to 2030, and compare them with current estimates of forest growth in the region. The flowchart in Figure 1 shows the various components of these forecasts.

NORTHERN MINNESOTA PULPWOOD CONSUMPTION IN PULP MANUFACTURE

The future consumption of northern Minnesota pulpwood used in pulp production is calculated in four steps:

1. We project pulp production for the entire State of Minnesota.
2. We determine the amount of pulpwood required to produce that amount of pulp.
3. We estimate the species composition of that pulpwood.
4. We project the volume of pulpwood that will originate from northern Minnesota for each species.

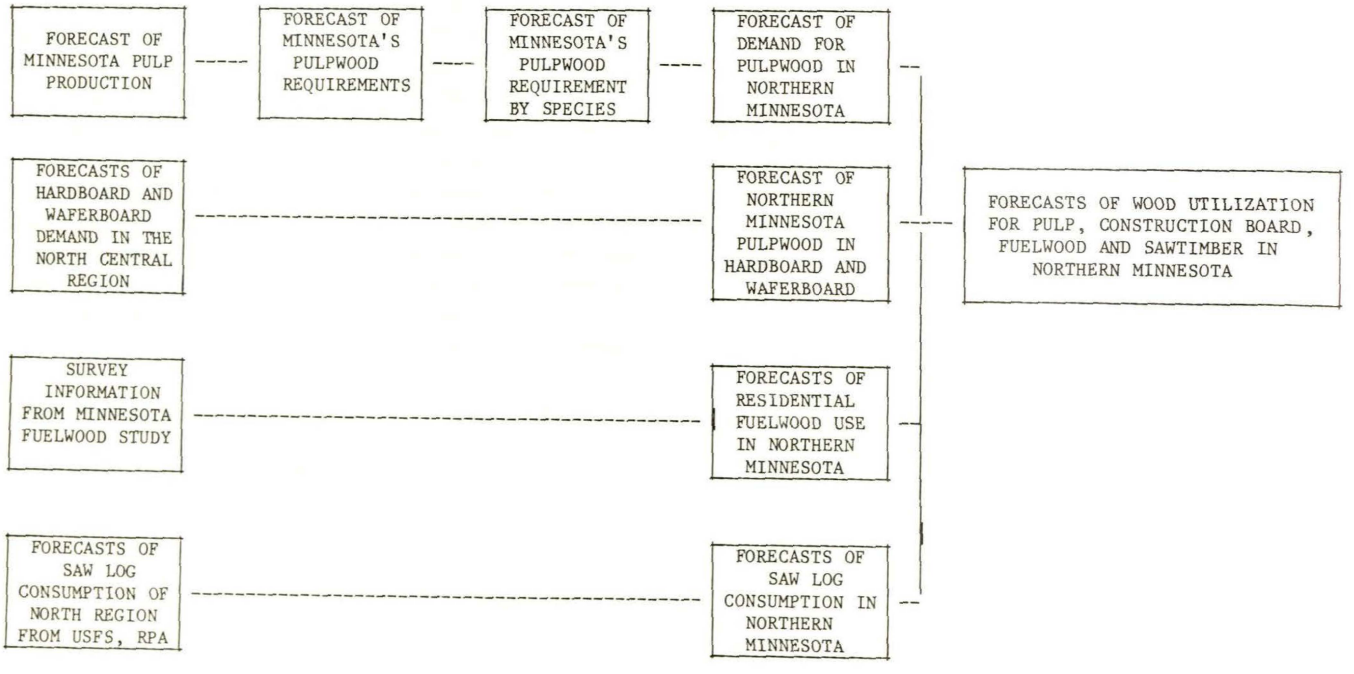
The remainder of this section describes the computations and models used in each step.

Projections of Minnesota Wood Pulp Production

The share of wood pulp produced in Minnesota has remained almost constant during the past decade, relative to production in the entire United States. We assume that this share, which averaged about 1.7 percent between 1967 and 1976 (table 1), will remain the same during the next 50 years. We further assume that national pulp production could develop along the low, medium, and high projections used by the Forest Service in its latest Assessment (USDA Forest Service 1980). These assumptions lead to projections that Minnesota pulp production could increase from about 900 tons in 1980 to 1.3 (low projection) to 1.5 (high projection) million tons by 2000 and to 1.8 (low projection) to 2.9 (high projection) million tons by 2030 (table 2). This is an increase of 44 to 67 percent by 2000 and an increase of 100 to 222 percent by 2030.

Projections of Pulpwood Consumption in Minnesota

As was done in the past, pulpwood requirements have been computed directly from pulp production, assuming that price effects are negligible (Adams 1975, Leuschner 1973). Forest Service data show that


FORECAST OF MINNESOTA PULP PRODUCTION
FORECAST OF MINNESOTA'S PULPWOOD REQUIREMENTS
FORECAST OF MINNESOTA'S PULPWOOD REQUIREMENT BY SPECIES
FORECAST OF DEMAND FOR PULPWOOD IN NORTHERN MINNESOTA
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FORECASTS OF SAW LOG CONSUMPTION IN NORTHERN MINNESOTA

Figure 1.—*Components of wood utilization forecasts for pulp, construction board, fuelwood, and sawtimber in northern Minnesota.*

Table 1.—*Share of Minnesota woodpulp production within total U.S. woodpulp production, 1967-1976*

Year	Minnesota[1]	United States[2]	Minnesota's share
	-----Thousand short tons-----		*------Percent------*
1967	652.2	36,677	1.8
1968	700.9	40,892	1.7
1969	736.4	42,8l3	1.7
1970	706.1	43,546	1.6
1971	738.0	43,903	1.7
1972	761.2	46,767	1.6
1973	791.5	48,327	1.6
1974	877.3	48,329	1.8
1975	789.7	43,084	1.8
1976	906.7	47,721	1.9
Average Market Share = 1.7 percent Standard Deviation = 0.1 percent			

[1]U.S. Department of Commerce, Bureau of the Census. Current industrial reports, pulp, paper and board. Series M26A. Washington, DC: U.S. Department of Commerce, Bureau of the Census; various years from 1968 to 1978.

[2]Table XXIV U.S. Production of Woodpulp 1967-1978 in Statistics of Paper and Paperboard, 1979. American Paper Institute 260, Madison Ave., New York (Oct., 1979).

the amount of pulpwood used per ton of pulp has changed little since 1920. The general shift from sulfite and soda to sulfate and semichemical processes, as well as the increasing use of hardwoods, has tended to increase the yield of pulp per cord of wood. Offsetting these trends, however, has been the increasing use in proportions of semibleached and bleached grades of wood pulp requiring more wood per ton of pulp than unbleached grades (USDA Forest Service 1980).

The ratio of cords of pulpwood to tons of pulp produced is estimated from data on pulpwood receipts and pulp production for Minnesota, 1952-1976 (table 3). Based on these data showing a current wood-to-pulp ratio of approximately 1.45 cords per ton and on RPA findings (USDA Forest Service 1980) regarding future technological developments, we assume that pulpwood use per ton of pulp produced will decline from 1.4 cords between 1980 and 1989 to 1.3 cords between 1990 and 2009 and to 1.2 cords between 2010 and 2030.

Table 3.—*Estimates of cords of wood per ton of pulp produced Minnesota*

Year	Minnesota pulp production[1]	Minnesota pulpwood receipts[2]
	Thousand tons	*Thousand cords*
1952	457*	720
1953	475*	662
1954	NA	687
1955	517*	723
1956	550*	835
1957	492*	753
1958	499*	699
1959	641*	813
1960	622	787
1961	654	784
1962	667	828
1963	601	921
1964	674	938
1965	NA	912
1966	701	1063
1967	652	958
1968	701	993
1969	736	1082
1970	706	1058
1971	738	1063
1972	761	1224
1973	791	1223
1974	877	1392
1975	790	1227
1976	907	1178
Cords per ton of pulp		
Average 52-61:	753 : 545 = 1.4	
Average 62-71:	981 : 686 = 1.4	
Average 66-76:	1,133 : 760 = 1.5	

[1]From pulp, paper, and board Current industrial Reports. U.S. Department of Commerce, published annually.

[2]From pulpwood production and consumption in the North Central Region. Published annually.

* Calculated as 95% of Regional total.

Table 2.—*Projected pulp production and corresponding pulpwood consumption in Minnesota, 1980-2030*

Year	U.S. pulp production[1]			Minnesota pulp production			Minnesota pulpwood requirements		
	Low projection	Medium projection	High projection	Low projection	Medium projection	High projection	Low projection	Medium projection	High projection
	----------Million tons----------						*---------Thousand cords---------*		
1980	51.8	52.3	52.8	0.9	0.9	0.9	1,247	1,259	1,271
1985	59.2	61.0	63.0	1.0	1.0	1.0	1,426	1,469	1,517
1990	68.0	71.6	75.7	1.2	1.2	1.3	1,520	1,601	1,693
2000	78.1	85.9	95.0	1.3	1.5	1.5	1,746	1,921	2,124
2010	87.8	100.2	116.5	1.5	1.7	2.0	1,812	2,068	2,404
2020	96.3	115.1	142.0	1.6	2.0	2.4	1,988	2,376	2,931
2030	102.4	128.9	169.1	1.8	2.2	2.9	2,114	2,660	3,490

[1]U.S. Forest Service (1980).

These yield coefficients and the previously computed projections of pulp production lead to projections that Minnesota pulpwood requirements could increase from a range of 1,746 thousand cords (low forecast) to 2,124 thousand cords (high forecast) by 2000 and to 2,114 thousand cords (low forecast) to 3,490 thousand cords (high forecast) by 2030 (table 2). These computations assume that most of the wood used by the Minnesota pulp industry will continue to come from the State (Blyth and Smith 1979).

Projections of Minnesota Pulpwood Consumption by Species

The procedure for dividing total Minnesota pulpwood requirements into three species groups (softwoods, aspen, and other hardwoods) uses two models. One model predicts the softwood and hardwood shares of the total pulpwood requirements. The second model predicts the aspen and other hardwood shares of the total hardwood pulpwood requirements.

Although we assume that pulpwood price will have little influence on total pulpwood use per unit of pulp production, relative prices among species groups will probably influence the species group shares of total pulpwood requirements. There is some flexibility regarding species mix although it is technologically difficult to reduce the amount of fiber used in paper manufacture. Thus, before statistically estimating equations for these two models and testing the price hypothesis, we had to construct price indices for total pulpwood and hardwood pulpwood. The procedure used, based on divisia price indices, is described in the appendix. The price series obtained are reported in the last two columns of table 4.

Two logit models were then developed to predict the effect of price changes on the share of softwoods, aspen, and other hardwoods within total Minnesota pulpwood consumption (see Appendix). These models are used to predict the species share during the next 50 years (1980-2030) (table 5). The softwood share of pulpwood used in Minnesota is projected to decrease from around 40 percent in 1976 to about 25 percent by 2000 and to about 10 percent by 2030. The aspen share of the hardwood pulpwood used in Minnesota is projected to remain about a constant 93 percent throughout the forecast period. The underlying assumptions regarding the future evolution of species group prices are presented in table 6. Specifically, we assume that the real price of softwood pulpwood in Minnesota will grow at the rate projected by the Forest Service for the softwood stumpage equilibrium price in the North Central region. Similiarly, we assume the prices of aspen and other hardwoods will grow at the rate projected by the Forest Service for the hardwood stumpage equilibrium price in the North Central region (USDA Forest Service 1980).

Table 4.—*Prices and quantities of pulpwood delivered to the mill in Minnesota, 1964-1976*
(In 1972 dollars)

Year	Softwood		Aspen		Other hardwoods		Pulpwood[3]	Hardwood[3] pulpwood
	Price[1]	Quantity[2]	Price[1]	Quantity[2]	Price[1]	Quantity[2]	Price	Price
	$/cord	*Thousand cords*	*$/cord*	*Thousand cords*	*$/cord*	*Thousand cords*	----------*$/cord*----------	
1964	24.5	562.0	14.1	451.0	13.8	45.5	16.3	14.1
1965	23.3	504.0	17.5	468.0	14.5	41.5	17.6	17.3
1966	25.2	515.0	18.2	612.0	15.6	32.0	18.7	18.1
1967	24.3	536.0	16.8	591.0	13.6	42.0	17.5	16.6
1968	23.0	429.0	17.3	538.0	13.3	23.0	17.3	17.1
1969	23.0	452.0	17.9	660.0	16.1	35.0	18.0	17.7
1970	25.3	483.0	15.6	600.0	15.6	58.0	17.6	15.6
1971	21.3	454.0	14.6	607.0	14.6	65.0	15.7	14.6
1972	22.0	505.0	15.0	689.0	14.0	72.0	16.0	14.9
1973	22.3	518.0	14.9	673.0	14.2	78.0	16.1	14.8
1974	27.8	541.0	14.0	804.0	14.4	80.0	17.3	14.0
1975	24.7	524.0	14.0	615.0	13.2	58.0	16.2	13.9
1976	23.2	422.0	13.8	673.0	12.5	78.0	15.6	13.7

[1]Prices obtained from Lothner, *et al.* 1982. Softwood price is a weighted average of jack pine and spruce prices. Hardwood price is the price of birch.

[2]Quantity data obtained from Blyth and Smith 1979. Softwood quantity consists of pine, spruce, balsam fir, and tamarack. Hardwood quantity consists of birch and other hardwoods.

[3]Pulpwood and hardwood prices constructed using the divisia index methodology (see appendix).

Table 5.—*Actual and predicted pulpwood species shares for Minnesota, 1964-2030*

Year	Softwood		Hardwoods		Aspen		Other Hardwoods	
	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted
1964	[1]0.53	[1]0.52	[1]0.47	[1]0.48	[2]0.91	[2]0.91	[2]0.09	[2]0.09
1965	.50	.47	.50	.53	.92	.94	.08	.06
1966	.44	.46	.56	.54	.95	.94	.05	.06
1967	.46	.46	.54	.54	.93	.95	.07	.05
1968	.41	.43	.59	.57	.96	.94	.04	.06
1969	.39	.41	.61	.59	.95	.94	.05	.06
1970	.42	.43	.58	.57	.91	.90	.09	.10
1971	.40	.40	.60	.60	.90	.90	.10	.10
1972	.40	.39	.60	.61	.91	.93	.09	.07
1973	.41	.39	.59	.61	.90	.92	.10	.08
1974	.38	.42	.62	.58	.91	.89	.09	.11
1975	.44	.39	.56	.61	.91	.93	.09	.07
1976	.36	.37	.64	.63	.90	.93	.10	.07
1980		.35		.65		.93		.07
1985		.32		.68		.93		.07
1990		.30		.70		.93		.07
2000		.24		.76		.93		.07
2010		.17		.83		.93		.07
2020		.15		.85		.93		.07
2030		.10		.90		.93		.07

[1]Fraction of total pulpwood use.
[2]Fraction of total hardwood pulpwood use.

Using the species share projections (table 5) and the pulpwood requirement projections (table 2), we determine the future consumption of pulpwood in Minnesota, by species (table 7).

Consumption Projections for Pulpwood Grown in Northern Minnesota

The volume of pulpwood grown in northern Minnesota and used in pulp production has remained a constant share of the volume consumed (and produced) in the entire State. This share has averaged about 0.95, 0.88 and 0.99 for aspen, other hardwoods and softwoods, respectively (table 8), during the 1973-1977 period. We assume these shares will continue at the same level over the projection period.

The projections of pulpwood grown in northern Minnesota used for pulp production are found in table 9. They are obtained by multiplying the species shares (table 8) and the State projections of pulpwood consumed in Minnesota pulp production (table 7).

The medium Forest Service projections imply that total pulpwood use will grow by about 109 percent over the next 50 years, to a total of 2,526 thousand cords, if all our assumptions are valid. The species composition of this volume will change considerably. Hardwoods, which currently account for 65 percent of the volume, will grow to 90 percent. Aspen will continue to make up most of that hardwood share. If we assume that the Forest Service low and high projections correspond to an estimate of the range of possible occurrences, pulpwood requirements from northern Minnesota could vary some 2.0 million to

Table 6.—*Future prices of pulpwood assumed in projections, 1980-2030*

(In 1972 dollars per cord)

Year	Softwood	Aspen	Project price other hardwood	Pulpwood	Hardwood pulpwood
1980	26.3	13.8	12.5	19.0	13.7
1985	30.6	13.8	12.5	20.4	13.7
1990	36.3	13.7	12.4	22.1	13.6
2000	42.6	12.9	11.7	23.2	12.8
2010	50.2	13.7	12.4	25.9	13.6
2020	74.4	15.4	13.9	33.4	15.2
2030	86.9	17.3	15.6	38.3	17.1

Table 7.—*Projections of pulpwood consumed for pulp production in Minnesota, by species, 1980-2030*

(In thousand cords)

Year	Low projection				Medium projection				High projection			
	Total	Softwoods	Aspen	Other hardwoods	Total	Softwoods	Aspen	Other hardwoods	Total	Softwoods	Aspen	Other hardwoods
1980	1,247	436	754	57	1,259	441	761	57	1,271	445	768	58
1985	1,426	456	902	68	1,469	470	929	70	1,517	485	959	72
1990	1,520	456	990	74	1,601	480	1,042	78	1,693	508	1,102	83
2000	1,746	419	1,234	93	1,921	461	1,358	102	2,124	510	1,501	113
2010	1,812	308	1,379	105	2,068	352	1,596	120	2,404	409	1,856	140
2020	1,988	298	1,572	118	2,376	356	1,878	141	2,931	440	2,317	174
2030	2,114	211	1,769	133	2,660	266	2,226	168	3,490	349	2,921	220

Table 8.—*Share of northern Minnesota pulpwood harvest relative to that of the entire State*[1]

Species	Year					Mean	S.D.
	1973	1974	1975	1976	1977		
Aspen	0.965	0.923	0.964	0.963	0.957	0.950	0.017
Other hardwoods	.930	.862	.924	.897	.818	.883	.043
Softwoods	.990	.991	.991	.987	.985	.988	.003

[1]Lake States pulpwood production from roundwood by species, State, and Forest Survey Unit, 1973-1977, (Blyth and Smith 1977).

Table 9.—*Projections of pulpwood grown in northern Minnesota used for pulp production, by species groups, 1980-2030*

(In thousand cords)

Year	Low projection				Medium projection				High projection			
	Total	Softwoods	Aspen	Other hardwoods	Total	Softwoods	Aspen	Other hardwoods	Total	Softwoods	Aspen	Other hardwoods
1980	1,197	431	716	50	1,209	435	723	51	1,220	440	730	51
1985	1,367	451	857	60	1,409	464	883	62	1,455	480	911	64
1990	1,456	451	940	66	1,534	475	990	69	1,622	502	1,047	73
2000	1,668	414	1,172	82	1,836	455	1,290	90	2,030	504	1,426	100
2010	1,726	304	1,329	93	1,970	342	1,516	106	2,290	404	1,763	123
2020	1,892	295	1,493	104	2,261	352	1,784	125	2,789	434	2,201	154
2030	2,007	209	1,681	118	2,526	263	2,115	148	3,314	345	2,775	194

3.3 million cords (table 10). Nevertheless, even the lowest projection will mean a 71-percent increase in demand.

NORTHERN MINNESOTA PULPWOOD CONSUMPTION IN CONSTRUCTION BOARD PRODUCTION

Recently, two new waferboard mills were built in Bemidji and an existing waferboard plant in Grand Rapids doubled its production. A fourth waferboard plant has been completed in Cook, but awaits start-up.

The primary market opportunities for these building products are in new residential construction (Dickerhoof and Marcin 1978). The demand for waferboard and particleboard is partly a function of how much they can be substituted for other construction materials. To determine the amount of northern Minnesota pulpwood that will be used in manufacturing these products, we first project the demand for the end products. This, in turn, leads to estimates of raw material requirements.

Market Area

We assume that the primary market area for waferboard and particleboard products from northern

Table 10.—*Projections of prices and housing starts used in estimating future consumption of construction board products in the North Central Region*

Year	Price indices (1967 = 100)					Housing starts[1]	
	P_S	P_L	P_R	P_M	P_W	High projection	Low projection
						-----Thousand units-----	
1980	140	128	100	132	233	432	399
1985	167	157	123	158	278	431	384
1990	202	194	152	191	336	385	336
2000	228	202	158	215	378	341	279
2010	252	214	167	238	418	413	333
2020	274	222	173	259	455	369	294
2030	299	232	181	283	496	370	294

[1] P_S = wholesale price indices of Douglas-fir softwood lumber (1967 = 100)
P_L = wholesale price indices of plywood (1967 = 100)
P_R = wholesale price indices of hardboard and waferboard (1967 = 100)
P_M = wholesale price indices of other construction materials (1967 = 100)
P_W = index of wages in construction (1967 = 100)
Source: Marcin, T. (1977).

Minnesota will be the North Central area (Dickerhoof and Marcin 1978). The North Central region encompasses 11 States including the Chicago market (Adams and Haynes 1980). Because waferboard is heavier than plywood of the same thickness (Koch 1978), we can expect that increasing transportation costs may limit the market area for waferboard and particleboard produced in northern Minnesota to the North Central region.

Because many of the mills in northern Minnesota are just beginning production, it is difficult to determine their market share (Carpenter 1980). The model described in the next section explicitly accounts for substituting the new waferboard products for plywood and softwood lumber. Whether waferboard manufactured elsewhere will compete in the North Central region remains an unanswered question. The most likely source of future competition will probably come from Canadian waferboard mills (Guss 1979). Because of the uncertainty of future developments, we assume that the market share for northern Minnesota mills will remain constant so that the supply of waferboard from these mills will grow in direct proportion to the demand from the entire North Central region.

Projections of Hardboard and Waferboard Consumption in the North Central Region

The demand for hardboard and waferboard is based on the estimated derived demand equation for hardboard and particleboard described in Rockel and Buongiorno (1982). Using duality theory, we obtained a derived demand function for hardboard and particleboard, consistent with a statistically determined cost function for residential construction. In the resulting model the quantity of hardboard and particleboard demanded is a function of the prices of softwood lumber, plywood, hardboard and particleboard, other materials, and labor, as well as the number of residential housing starts, and a time trend. The equation takes into account the price elasticity of hardboard and particleboard as well as the cross price elasticities of substitution with other inputs. This is of particular importance with respect to waferboard because it competes in price and function with CDX softwood plywood (Koch 1978). The empirical equation used to forecast hardboard and waferboard demand is (Rockel and Buongiorno 1982).

$$\begin{aligned}\triangle D/D = {} & \underset{(0.02)^{**}}{0.09}\ \triangle P_S/P_S + \underset{(0.02)^{**}}{0.05}\ \triangle P_L/P_L \\ & \underset{(0.03)^{**}}{-\ 0.95}\ \triangle P_R/P_R \\ & \underset{(0.03)^{**}}{+\ 0.12}\ \triangle P_M/P_M + \underset{(0.02)^{**}}{0.68}\ \triangle P_W/P_W \quad (1) \\ & \underset{(0.005)^{**}}{+\ 0.982}\ \triangle Q/Q + \underset{(0.0015)^{**}}{0.0108}\end{aligned}$$

where $\triangle D/D$ is the yearly relative change in the quantity of hardboard and waferboard demanded in the North Central region, $\triangle P_S/P_S$, $\triangle P_L/P_L$, $\triangle P_R/P_R$, $\triangle P_M/P_M$, $\triangle P_W/P_W$ are the yearly relative changes in prices of softwood lumber, plywood, hardboard and waferboard, other materials, and labor, respectively. $\triangle Q/Q$ is the yearly relative change of residential

housing units in the North Central region. The numbers in parentheses are standard errors. ** indicates a coefficient significantly different from zero at the 0.99 confidence level.

Projections of demand using equation (1) require projections of the independent variables. We assumed that the price of other materials (P_M), labor (P_W) and lumber (P_X) would grow as fast as the price for softwood lumber. Similarly, waferboard prices (P_R) and plywood prices (P_L) would grow as fast as pulpwood price during the next 50 years (USDA Forest Service, 1980).

Projections of residential housing starts in the North Central region were obtained from Marcin (1977). Two sets of housing projections, high and low, were used (table 10).

Construction board consumption forecasts in the North Central region are obtained by applying the independent variable assumptions for the prices of softwood lumber (P_S), plywood (P_L), waferboard (P_R), other materials (P_M), and labor (P_W) (table 10) to equation (1). With these assumptions, the model projects that construction board consumption will increase in a range of 1,209 MMSF (low projection) to 1,516 MMSF (high projection) by 2030. This is a 45- percent (low projection) to 70-percent (high projection) increase over the next 50 years (table 11). Forest Service assessment projections (USDA Forest Service 1980) are also reported for comparison. The Forest Service assessment report predicts a faster rate of growth in the early years, but lower levels by the end of the projection period. Our low projection of consumption for board is near the high Forest Service assessment projections (table 11). The broad range of projections underlines the high uncertainty faced in doing such long-term projections. The projections in this report are closely tied to housing forecasts, as are the projections in the assessment report. However, even as housing starts decline after the year 2010 (table 10), consumption of board products still increases due to the substitution of these products for more expensive ones, notably lumber and plywood. Our projection accuracy, therefore, depends on the validity of our future price assumptions and the accuracy of our elasticity of substitution estimates.

Table 11.—*Projections of construction board consumption in the North Central region (1980-2030)*
(In million square feet, ½")

Year	This report[1]		Forest Service[2]	
	High projection	Low projection	High projection	Low projection
1980	898	830	816	754
1985	918	819	929	828
1990	848	742	963	840
2000	901	740	994	813
2010	1,260	1,020	1,249	1,007
2020	1,308	1,047	1,200	956
2030	1,516	1,209	1,231	978

[1]Includes hardboard and particleboard (including waferboard, flakeboard, composite board, and medium density fiberboard).

[2]Includes hardboard, insulating board, and particleboard (including waferboard, flakeboard, composite board, and medium density fiberboard) (U.S. Forest Service 1980).

Projections of Northern Minnesota Pulpwood Used in Hardboard and Waferboard Manufacture

Our projections are made using projections for the entire North Central region and assuming the northern Minnesota mills will maintain a constant 57-percent share of the market. We assume timber requirements will originate from these same northern Minnesota counties. We further assume that 1.16 cords of wood will be required per thousand square feet of 1/2 inch board (Harpole 1978). No attempt is made to distinguish the raw material by species but we expect that most of it will be aspen (Carpenter 1978). In our analysis we assume construction board production will increase to a range of 686 thousand cords (low forecast) to 860 thousand cords (high forecast) by the year 2030 (table 12).

FUELWOOD CONSUMPTION IN NORTHERN MINNESOTA

The energy crisis and the related increase in the price of heating fuels since 1973 have increased the interest in using fuelwood for residential heating and for energy. A survey carried out during the 1979-1980 heating season (Minnesota DNR 1981) indi-

Table 12.—*Projections of Northern Minnesota aspen pulpwood used for construction board production, 1980-2030*
(In thousand cords)

Year	High projection	Low projection
1980	509	971
1985	521	465
1990	482	421
2000	511	420
2010	715	579
2020	742	594
2030	860	686

cates that 33 percent of Minnesota households used some amount of fuelwood during the 1978-1979 winter season. In northern Minnesota, about 45 percent of households did so. In addition, many of the pulp and paper mills in the region use wood chips and residues to fire their boilers. It is estimated that the pulp, paper, and paperboard industry obtained 47 percent of its energy from waste fuels in 1980 (Pulp and Paper 1981). However, not all residues and wastes generated in production are yet being used. Any increase in the use of wood as an energy source within the industry will probably arise from better utilization of wood already being harvested rather than from additional harvest. The consumption of wood for fuel by the pulp industries has already been accounted for in estimating northern Minnesota pulpwood requirements for pulp production. Consequently, we only develop projections of residential fuelwood consumption.

Our projections rely heavily on the 1979-1980 Minnesota Department of Natural Resources fuelwood utilization survey, described below.

The 1979-1980 Minnesota Fuelwood Utilization Survey

The Minnesota Department of Natural Resources conducted a survey of fuelwood use during the heating season 1979-1980 in all Minnesota forest survey units. Respondents were classified into households that burn wood as:

(a) A major source of heat,
(b) A secondary source of heat,
(c) Mostly for aesthetic considerations.

The survey also estimated the amount of fuelwood used by each category of user. In survey unit 1 (aspen-birch) about 45 percent of all households used fuelwood in some manner and 21 percent of households were major users. In survey unit 2 (northern pine) 54 percent of all households used fuelwood and 37 percent of households used it as a major source of fuel. Total use of fuelwood averaged 2.1 and 3.2 cords per household in survey units 1 and 2, respectively. The 1979-1980 survey showed the species distribution for the entire State only, but specific data for survey units 1 and 2 were available from a previous survey (Minnesota Department of Natural Resources 1980). Hardwoods represented about 72 percent of all fuelwood use, aspen represented about 23 percent, and softwoods represented 5 percent. The major survey data used in our projections are presented in table 13.

Table 13.—*Summary of findings of the 1979-1980 Minnesota Department of Natural Resources fuelwood consumption survey used to project fuelwood consumption in northern Minnesota (Minnesota DNR 1981.)*

	Survey units	Type of use			
		Major	Secondary	Pleasure	Total
Households using fuelwood (percent)	1	21	15	9	45
	2	37	12	5	54
Wood use (standard 4′ x 4′ x 8′ cds/ household/ yr)	1	6.8	3.2	1.6	2.1
	2	7.1	3.7	1.9	3.2
		Hardwoods	Aspen	Softwoods	
Species used[1] (percent)	1	72	24	4	
	2	71	23	6	

[1]Data on species noted are from Minnesota DNR (1980).

Projections of Residential Fuelwood Use in Northern Minnesota

Our projections assume that the pattern of wood burning will not differ significantly from that determined by the 1979-1980 Minnesota Department of Natural Resources survey described above. The only source of growth will be the increase in the number of households in the region. Therefore, resulting estimates could be conservative because they ignore further increases in fossil fuel prices. On the other hand, the statewide fuelwood survey has shown that the percentage of households that burn wood, especially for heating, is closely related to wood availability (Minnesota Department of Natural Resources 1980). The projected increase in wood for industrial uses will limit the wood supply and increase either the market or the procurement cost of timber, including fuelwood. To accurately project what will happen to fuelwood prices and their effect on fuelwood utilization is difficult. We make the simple assumption that the two sets of forces just described will to some extent compensate each other.

The future number of households in northern Minnesota is predicted by assuming the same growth rates of household formation predicted by Marcin for the North Central region (Marcin 1977) and used by the Forest Service for the latest timber assessment

Table 14.—*Projections of households in northern Minnesota, 1980-2030*[1]
(In thousand units)

Year	Total		Survey Unit 1		Survey Unit 2	
	High projection	Low projection	High projection	Low projection	High projection	Low projection
1980	187	187	104	104	83	83
1985	200	198	111	110	89	88
1990	211	207	117	115	94	92
2000	224	218	124	121	100	97
2010	240	229	133	127	107	102
2020	251	240	139	133	112	107
2030	268	253	148	139	120	114

[1]Projections based on Minnesota DNR base year population (Minnesota DNR 1981) and household formation growth rates for the North Central Region (Marcin 1977).

(USDA Forest Service 1980). High and low forecasts were obtained, using Forest Service assumptions. The Minnesota Department of Natural Resources fuelwood survey data population projections are made for the two survey units in northern Minnesota (table 14).

Based on the household formation forecasts and the fuelwood utilization data, we project residential fuelwood use (table 15). The high projection shows a 43-percent increase in fuelwood use over the next 50 years; the low projection is only slightly lower. The major part of the residential fuelwood volume is hardwood. Aspen represents about 24 percent of the hardwoods total volume.

PROJECTIONS OF CONSUMPTION OF SAW LOGS GROWN IN NORTHERN MINNESOTA

To give a complete picture of the future consumption of all timber grown in northern Minnesota, we project the consumption of sawtimber (also equal to removals, or production). We stress, however, that the results are only indications.

Softwood saw log output in the State of Minnesota declined from 1960 to 1975, while hardwood saw log output increased slightly (table 16). However, the rates of growth vary greatly depending on which years are used as reference. We compare these trends with the growth of saw log production in the entire Northern Region (USDA Forest Service 1980). During 1952 to 1976, softwood saw log production grew very little in the Northern Region, while hardwood saw log production grew at an annual rate of between 1 and 2 percent (table 17). Because only limited data are available, it is not possible to establish any testable relation between removals in Minnesota and the Northern Region, let alone between northern Minnesota and the Northern Region.

Therefore, we make the simple assumption that saw log removals in Minnesota, for both hardwoods and softwoods, will grow at the same rate as in the entire Northern Region. In addition, we assume that the share of removals from northern Minnesota, relative to all Minnesota, will remain constant. These shares were recently estimated as 98 percent for softwoods and 66 percent for hardwoods (Blyth *et al.* 1980). Our projections indicate that softwood saw log production will increase from 128 thousand cords in

Table 15.—*Projections of residential fuelwood in Northern Minnesota, by major species group, 1980-2030*
(In thousand cords)

Year	Residential fuelwood consumed							
	Total		Softwood		Aspen		Other hardwoods	
	High projection	Low projection	High projection	Low projection	High projection	Low projection	High projection	Low projection
1980	484	484	24	24	114	114	346	346
1985	516	512	26	26	122	120	369	366
1990	545	535	27	27	128	126	390	383
2000	579	563	29	28	136	132	414	403
2010	620	592	31	30	146	139	443	423
2020	649	621	32	31	153	146	464	444
2030	693	654	35	33	163	154	496	468

Table 16.—*Saw log production in Minnesota, 1960-1975*[1]

Year		1960	1973	1975
		-Million board feet, Intl. ¼" log rule-		
Softwoods		76.1	55.2	60.9
Hardwoods		92.0	122.3	95.2
		----------Percent per year----------		
Rates of Growth of Softwoods	1960-1973	−2.4		
	1960-1973	−2.4		
Rates of Growth of Hardwoods	1960-1973	2.2		
	1960-1975	0.2		

[1]Blyth *et al.* (1980), Blyth and Smith (1979).

Table 17.—*Saw log production in the Northern Region*[1], *1952-2030*

Year		1952	1962	1970	1976
		Million board feet, Int. ¼" log rule			
Softwoods		1,624	1,271	1,784	1,928
Hardwoods		3,729	3,998	5,298	4,996
		----------Percent per year----------			
Rates of Growth of Softwood	1952-1970: 0.5				
	1952-1976: 0.7				
Rates of Growth of Hardwood	1952-1970: 2.0				
	1952-1976: 1.2				

[1]USDA Forest Service Northeast, North, and North-Central Regions (USDA Forest Service 1980).

1980 to 196 thousand cords in 2030 in northern Minnesota, an increase of 53 percent (table 18). Hardwood saw log production in northern Minnesota is projected to rise from 127 thousand cords in 1980 to 207 thousand cords in 2030, a 63-percent increase. To determine the aspen share of all hardwood production in northern Minnesota, we assume that 74 percent of hardwood removals will be aspen, as observed in Jakes and Raile (1980) and Spencer and Ostrom (1979).

PROJECTIONS OF CONSUMPTION OF TIMBER GROWN FOR PULP, CONSTRUCTION BOARD, FUELFOOD, AND LUMBER

The aggregate projections of consumption of pulpwood, fuelwood, and saw logs produced from northern Minnesota forests are reported in table 19. They were obtained by adding the corresponding entries from table 7 (consumption for pulp production), table 12 (consumption for manufacture of construction board), table 15 (consumption for fuelwood), and table 18 (consumption for saw logs). Only low and high projections are presented because intermediate projections consistent with Forest Service assumptions in the Analysis of the Timber Situation in the United States could be obtained only for pulpwood used in pulp manufacture.

Table 18.—*Estimates of past saw log production and projections for the Northern Region, Minnesota and northern Minnesota for selected years*

	1960	1975	1980	1985	1990	2000	2010	2020	2030
	----------Million board feet intl. ¼" log rule----------								
Northern Region[1]									
Softwoods	1,296	1,902	1,947	1,972	1,997	2,271	2,512	2,747	2,976
Hardwoods	3,972	5,044	4,863	4,702	4,548	5,403	6,272	7,222	7,932
Minnesota[2]									
Softwoods	76.1	60.9	62.4	63.2	64.0	72.7	80.3	87.8	95.1
Hardwoods	92.0	95.2	91.8	88.7	85.8	101.8	118.0	135.8	149.1
Northern Minnesota[3]									
Softwoods	74.1	59.8	61.1	61.9	62.7	71.2	78.7	86.1	93.2
Hardwoods	48.7	62.5	60.6	58.6	56.6	67.2	77.9	89.6	98.4
	----------Thousand cords----------								
Softwoods	156	126	128	130	132	150	165	181	196
Hardwoods	102	131	127	123	119	141	164	188	207
Aspen[3]	75	97	94	91	88	104	121	139	153
Other hardwoods	27	34	33	41	31	37	43	49	54

[1]Data for 1960 and 1975 estimated from data in Table 17; data for 1980 to 2030 obtained from the Analysis of the Timber Situation in the United States (U.S. Forest Service 1980).

[2]Data for 1960 estimated from published and unpublished data from 1960 survey, data for 1975 from Blyth *et al.* (1980).

[3]Assuming the same species shares as in 1977 (Jakes and Raile 1980, Spencer and Ostrom 1979).

Table 19. —*Summary projections of consumption of timber grown in northern Minnesota for pulp, construction board, fuelwood, and sawtimber, by species, 1980-2030*

(In thousand cords)

	Wood utilization							
	Low projection				High projection			
Year	Total	Softwoods	Aspen	Hardwoods	Total	Softwoods	Aspen	Hardwoods
1980	1,957	588	933	436	2,519	547	1,485	437
1985	2,665	612	1,578	475	2,816	641	1,693	482
1990	2,728	615	1,625	488	2,971	667	1,800	504
2000	3,020	597	1,890	533	3,505	689	2,252	564
2010	3,292	503	2,218	571	4,069	605	2,838	626
2020	3,572	510	2,451	611	4,691	653	3,351	687
2030	3,857	440	2,762	655	5,447	580	4,097	770

The aggregate projections indicate that total consumption of northern Minnesota pulpwood, fuelwood, and saw logs will grow between 97 percent (low forecast) and 116 percent (high forecast) over the 1980-to-2030 period, leading to final consumption of 3,851 to 5,449 thousand cords in 2030, depending on the set of assumptions made. The range between the two projections underline the great uncertainty surrounding these projections.

These aggregate projections of consumption can be compared with preliminary estimates of current growth. The net annual growth of growing stock for northern Minnesota (Survey Units 1 and 2) is currently about 3,400 thousand cords per year, for all species. This is slightly below the low projection for the year 2030 in table 19. The net growth of aspen is approximately 1,600 thousand cords per year—much below the low projection of consumption in table 19. Some other species must be substituted for aspen if even the low projection in table 19 is to be met. Nevertheless, it seems that the low projection can be achieved assuming a minimum level of management and an active program of substituting other species for aspen. On the other hand, the high projection would require a large investment in forest management to increase productivity in northern Minnesota, especially for aspen.

We emphasize that this analysis represents a simple, straightforward approach to the problem of assessing consumption of timber produced in a small area like northern Minnnesota. As more comprehensive data on timber supply and consumption patterns become available, these projections will be revised.

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APPENDIX

Divisia Price Indices for Pulpwood

We chose to construct divisia indices of the pulpwood price for use in the share equations. The pulpwood divisia indices are based upon the theoretical concept that producers minimize costs of production by using various species in proportions so that their marginal productivities are equal to their purchase prices. These indices can be interpreted as using marginal productivities to weight prices (Hulten 1973). The divisia index is consistent with the translog production function (Christensen *et al.* 1973) used here (Christensen 1975). The specific form of the function is

$$\ln P = \sum_{i=1}^{n} \alpha_i \ln P_i + \sum_{i=1}^{n}\sum_{j=1}^{n} \gamma_{ij} \ln P_i \ln P_j + \epsilon_t \quad \text{(A1)}$$

where P is the price index for the group of species under consideration, P_i is the price of species i, n is the number of species in the group. ϵ_t is a random residual.

The constants α and γ relate to characteristics of the underlying cost and dual production function. Homogeneity of costs of degree one in prices impose that (Berndt and Christensen 1973):

$$\sum_{i=1}^{n} \alpha_i = 1, \quad \sum_{i=1}^{n} \gamma_{ij} = \sum_{j=1}^{n} \gamma_{ij} = 0$$

Logarithmic differentiation of (1) and application of Shephard's lemma (Diewert 1974) lead to the share equations:

$$M_i = \alpha_i + \sum_j \gamma_{ij} \ln P_j + \epsilon_{it} \quad i = 1,\ldots,n \quad \text{(A2)}$$

where M_i is the value share of species i relative to the value of total pulpwood use in Minnesota.

Data on pulpwood production in Minnesota, by species, for the period 1964 to 1976 were obtained from Blyth *et al.* (1980) and from Blyth and Smith (1979). Prices of pulpwood delivered to the mill were obtained from Lothner *et al.* (1982). Prices were deflated by the GNP price deflator (U.S. Department of Commerce 1980) to given prices in 1972 dollars.

Using the data reported in table 4, we estimated the share equations (A2) simultaneously using Zellner's (1962) efficient estimation procedure. The following price equations were obtained:

$$\begin{aligned} P_p = {} & 0.39\ P_a + 0.43\ P_s + 0.13\ P_b + 0.001\ P_a P_b \\ & (0.22) \quad (0.23)^* \quad (0.03)^{**} \quad (0.014) \\ & + 0.02\ P_a^2 - 0.02\ P_a P_s - .01\ P_s P_b + 0.01\ P_s^2 \\ & (0.0006)^{**} \quad (0.01)^{**} \quad (0.01) \\ & + 0.004\ P_b^2 \\ & (0.007) \end{aligned} \quad \text{(A3)}$$

$$\begin{aligned} P_h = {} & 0.91\ P_a + 0.09\ P_b + 0.22\ P_a^2 + 0.22\ P_b^2 \\ & (0.006)^{**} \quad (0.006)^{**} \quad (0.05)^{**} \quad (0.05)^{**} \\ & - 0.44\ P_a P_b \\ & (0.05)^{**} \end{aligned} \quad \text{(A4)}$$

Where p_p and P_h are the divisia prices of total pulpwood and hardwood, respectively. P_a and P_s are the prices of aspen and softwood; P_b is the price of birch used as an indicator of the price of other hardwoods. The numbers in parenthesis are standard errors. * and ** indicate coefficients significantly different from zero at the 0.95 and 0.99 confidence interval, respectively. The price series obtained by applying equations (A3) and (A4) are reported in the last two columns of table 4.

Models of Pulpwood Species Shares

We developed two models for allocating total Minnesota pulpwood consumption to species groups (softwoods, aspen, and other hardwoods). The first model develops a relation for dividing total Minnesota pulpwood consumption into the softwood and hardwood pulpwood shares and follows the logistic law:

$$S_{st} = Q_{st}/Q_{pt} = 1/(1 + \exp.(\beta_0 + \beta_1 \frac{P_s}{P_p} + \beta_2 t + \epsilon \quad \text{(A5)}$$

$S_{nt} = 1 - S_{st}$, $0 \leq S_{st} \leq 1$, $0 \leq S_{ht} \leq 1$, and $Q_{pt} = Q_{st} + Q_{ht}$

where:

S_{st} = relative share of softwood pulpwood in year t

S_{ht} = relative share of hardwood pulpwood in year t

Q_{pt} = total volume of pulpwood consumed in year t

Q_{st} = volume of softwood pulpwood consumed in year t

Q_{ht} = volume of hardwood pulpwood consumed in year t
P_s = the price of softwood pulpwood
P_p = the price of all pulpwood determined in the previous section by the divisia index method
t = time, a proxy variable for technological change
ϵ_t = random residual
$\beta_0, \beta_1, \beta_2$ = constant coefficients

The relation for dividing total hardwood pulpwood requirements into the aspen and other hardwood pulpwood shares follows a similar logistic law:

(A6)

$$S_{st} - Q_{at}/Q_{ht} = 1/(1 + \exp.(\beta_0 + \beta_1 \frac{P_a}{P_h} + \beta_2 t + \epsilon_t)$$

$S_{ot} = 1 - S_{at}$' $0 \leq S_{at} \leq 1$, $0 \leq S_{ot} \leq 1$, and $Q_{ht} = Q_{at} + Q_{ot}$

where:
S_{at} = relative share of aspen pulpwood in year t
S_{ot} = relative share of other hardwood pulpwood in year t
Q_{at} = volume of aspen pulpwood consumed in year t
Q_{ot} = volume of other hardwood pulpwood consumed in year t
P_a = price of aspen pulpwood
P_h = the price of hardwood pulpwood determined in the previous section by the divisia index
Q_{nt}, t, β_0, β_1, and β_2 are defined above.

The logit models (A5) and (A6) have attractive properties for analyzing interspecies competition. For example, in equation (A5) one would expect the coefficient β_1 to be positive so that if the price of softwood pulpwood decreases relative to hardwood pulpwood, the share of softwood pulpwood used in pulp production increases towards a maximum of unity or 100 percent. However, as the share of softwood pulpwood increases, greater relative price changes are needed to induce a marginal change in the softwood pulpwood share. Symmetrically, as the relative price of softwood pulpwood increases, the softwood pulpwood share declines asymptotically towards zero.

The logit models can be easily linearized for estimation. For example, model (A5) can be written:

(A5)

$$ln\,(Q_{pt}/Q_{st} - 1) = \beta_0 + \beta_1 \frac{P_s}{P_p} + \beta_2 t + \epsilon_t$$

However, the variance of the residuals is not constant. To correct for heteroscedasticity, generalized least squares estimates can be obtained by weighting all observations by the quantity (DeGroot 1976):

$w_t = (Q_{st}\,(Q_{pt} - Q_{st})/(Q_{pt} - 1))^{1/2}$ where w_t is the weight of the observations in year t and the other terms were defined above.

The estimation results using models (A5) and (A6) appear in table 20. The price coefficients (β_1) have the expected positive sign and are highly significant. Therefore, in equation (A5) as the price of softwood pulpwood increases relative to hardwood pulpwood, the softwood pulpwood share declines asymptotically towards zero. In equation (A6) as the relative price of aspen pulpwood to other hardwood pulpwood decreases, the share of aspen pulpwood increases towards unity or 100 percent. The time trend coefficient (β_2) was negative and significant in the softwood share equation (A5) indicating that technological change has led to a decrease in the softwood pulpwood share. The time trend did not play a significant role in the aspen share equation (A6) and was, therefore, omitted from the final model.

As indicated by the coefficients of determination, and by a comparison of actual against predicted values during the sample period (table 5), the logit models explain well the changes in the species composition of pulpwood used in Minnesota.

Table 20.—*Estimated logit models of softwood and aspen shares of pulpwood consumed in Minnesota, 1964-1976*

Parameters	Share of softwood relative to all pulpwood	Share of aspen relative to hardwood pulpwood
0	−1.16	−57.6
	(0.49)**	(21.3)**
1	0.86	59.8
	(0.36)**	(21.1)**
2	−0.05	—
	(0.01)**	
N	13	13
SSR	0.0004	0.024
R^2	.76	.88

** indicate coefficients significantly different from zero at the 99 percent confidence level.
N = number of observations, SSR = sum of squared residuals, R^2 = coefficient of determination.

Rockel, Mark; Buongiorno, Joseph; Lothner, David C.; Kallio, Edwin.
Future consumption of timber grown in northern Minnesota: 1980-2030. Res. Pap. NC-244. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1983. 15 p.

Consumption projections are reported by major species groups in northern Minnesota for pulpwood used in pulp production and in construction board, fuelwood, and sawtimber from 1980 to 2030. Total consumption of pulpwood could grow between 97 percent and 116 percent.

KEY WORDS: Pulpwood, fuelwood, sawtimber, divisia indices, aspen, other hardwoods, logit models, softwood.

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